William W. Hay Railroad Engineering Seminar

“Engineering Strategy and Technology Overview”

Kenneth Sito

Senior Assistant Vice President Engineering

Union Pacific Railroad

Date: Friday, April 15, 2016 Time: Seminar Begins 12:20 pm

Location: Newmark Lab, Yeh Center, Room 2311
University of Illinois at Urbana-Champaign

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NURail Center

Engineering

Strategy and Technology Overview

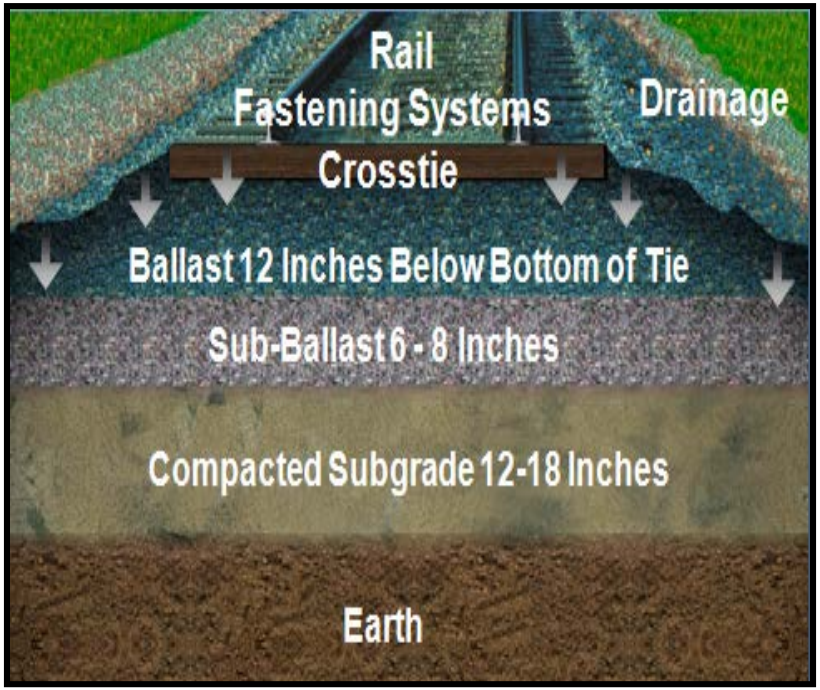
April 2016

Engineering Objectives

- **Safe operating conditions for employees, customers and communities**
- **Minimize train delay by reducing slow orders and maintenance footprint**
- **Cost effective results**

Infrastructure Strategies & Technologies

Major track systems overview



Ties

- 89 million wood ties assessed & replaced with strategic tie replacement (STR)
- 11 million concrete ties assessed with geometry systems & visual inspection
- 1 million composite ties assessed annually & replaced to minimize risk
- 4,200 miles of concrete tie pads assessed with geometry systems & visual inspection

Rail

- 6,735 curve miles inspected by geometry system & visual inspections.
- 29,374 mainline miles inspected by geometry & DC systems.
- Grinding performed by:
  - 3 Loram 400 Series grinders
  - 1 Loram SG grinder
- 3,309 total wayside lubricators, 2,455 gage face & 854 top of rail

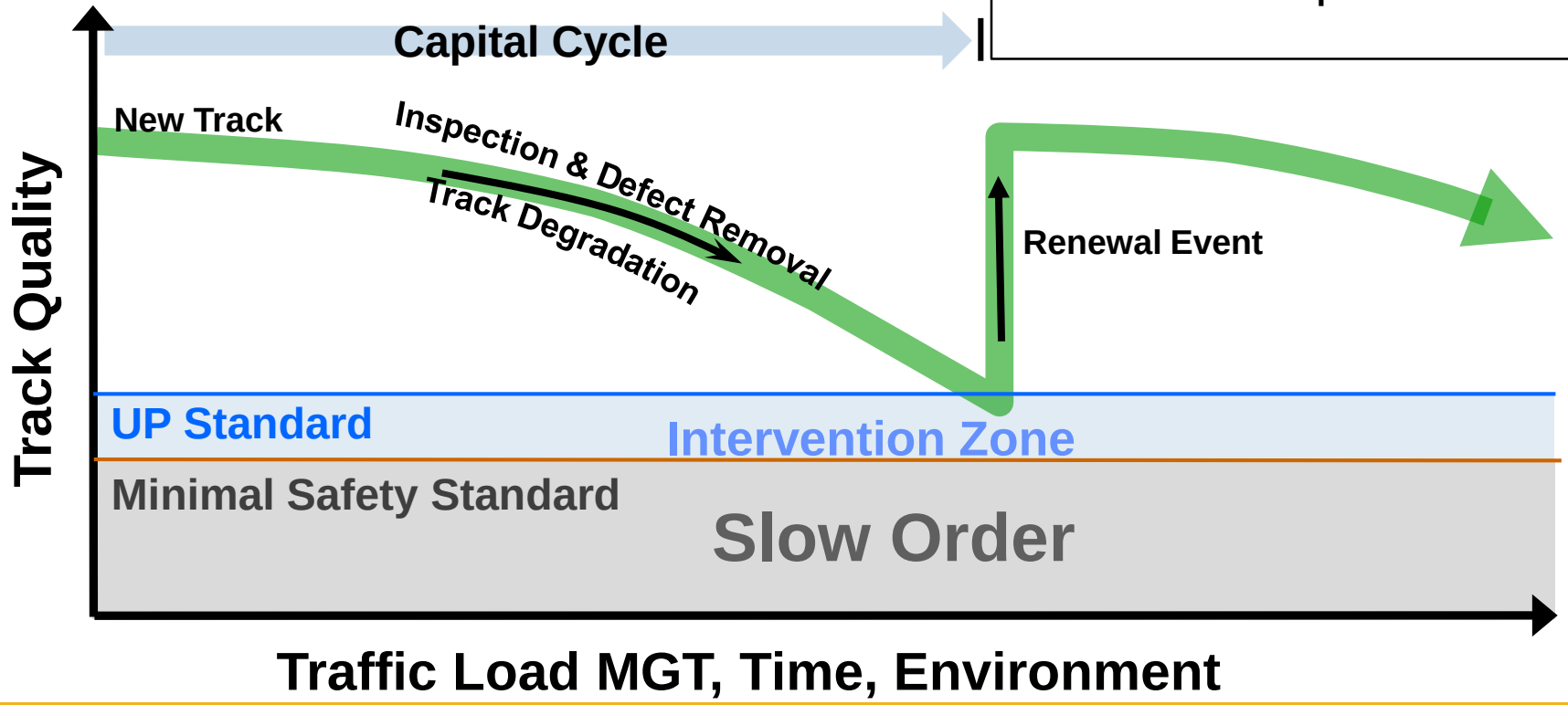
Roadbed

- Geometry assessed with:
  - 2 railbound evaluation cars, covering system 1-2 times/year
  - 5 Vista hyrail trucks serving Regions on high priority routes
  - 1 Vista unattended railcar platform (testing through mid-2016)
- Roadbed assessed with geometry systems, geotechnical inspections, chronic slow order history, ground penetrating radar (GPR) mounted on EC car
- Undercutting (BUC) program assessed with geometry systems, chronic slow order history, mud locations and ballast fouling model
- Precision Measurement Vehicles & Clearance hyrail platforms provide facility measurements for PTC & freight clearances
- Geotechnical engineering consultants provide most roadbed engineering design solutions

Predict & Prevent

Asset renewal strategy

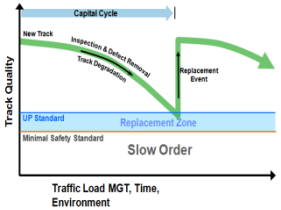
Overall Goal is to extend asset life and reduce or eliminate Capital Cycles to drive the lowest possible TCO.

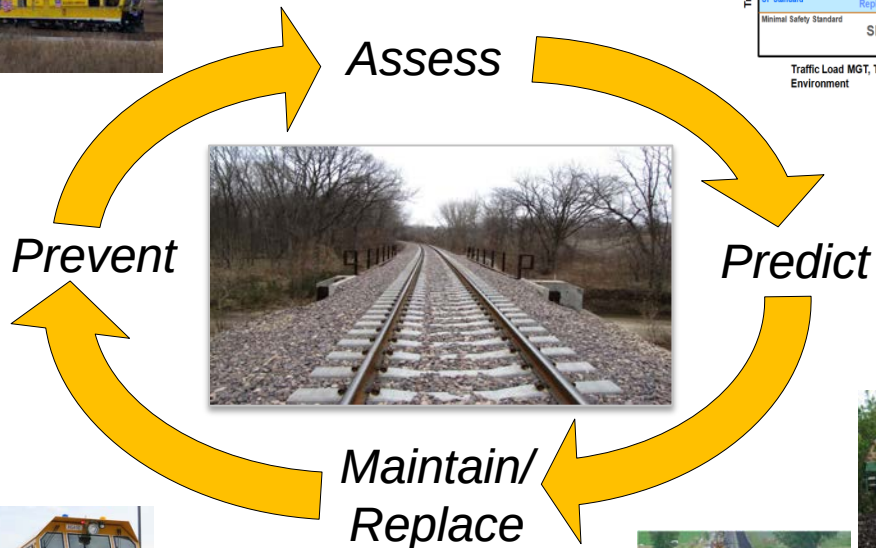


Assessment and Life Cycle Asset Management

Process drives renewal to highest impact areas

Track Asset Life Cycle

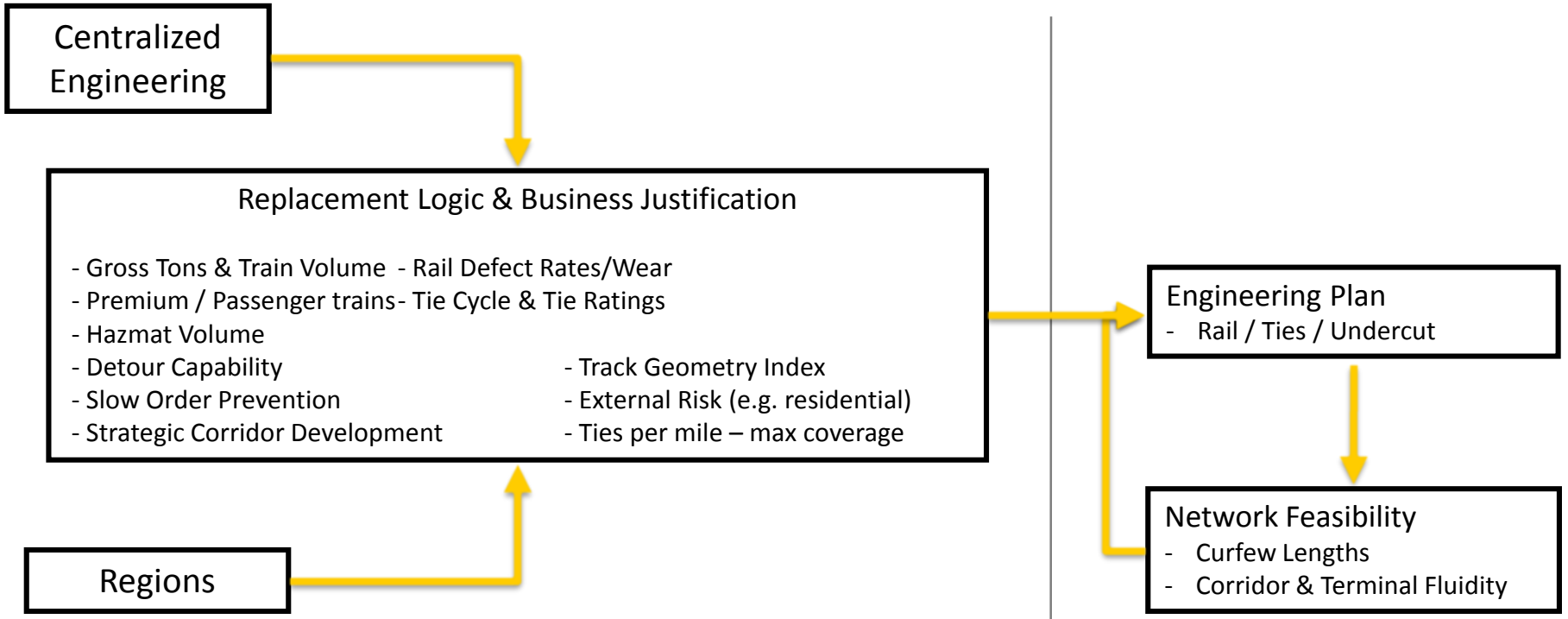




- **Assess**
  - Both visual and automated (i.e., geometry car, detector car, ground penetrating radar, VTI)
- **Predict**
  - Life cycle models based on history and statistical analysis
- **Maintain / Renew**
  - Best Components/Technology
  - Renewal program
  - Daily maintenance
- **Prevent**
  - Tactical maintenance
  - Strategic maintenance

Engineering Maintenance Capital Planning Process

Top-Down & Bottom-Up Responsibility



Crosstie Technology Progression

Implementation on UP

1865	1986	1998
		
Wood Ties	**Concrete**	**Composite**
87MM (27k Miles)	**10.2 MM (3900 Miles)**	**1 MM**

Can we Sustain our Wood Tie Strategy?

- **Headwinds (Challenges)**
  - Quality of timber (Tie Life)
  - Environmental pressure on creosote
  - Cost of solid sawn wood
  - Disposal Cost
  - Heavy Axle Load stresses
  - Renewal footprint demands
- **Tailwinds (Opportunities)**
  - Borate can buy us time
  - Composite Ties have the best long-term TCO for Wood Tie Replacement
  - Composite Tie Quality is Critical

Wood Tie Assessments

- **Strategic tie replacement provides effective and economic tie replacement cycles to ensure a safe infrastructure with maximum system velocity.**

Waco Sub reverse tie order — Total Ties To Replace: 380 Degraded Ties:

123 C = Needs Replaced(C = Concrete) 123 = Good 123 = Degraded

123 = Remaining Fair Ties 123' = Skip(123' = feet skipped)

1 W	2 W	3 W	4 W	5 W	6 W	7 W	8 W	9 W	10 W	11 W	12 W	13 W
29 W	30 W	31 W	32 W	33 W	34 W	35 W	36 W	37 W	38 W	39 W	40 W	41 W
57 W	58 W	59 W	60 W	61 W	62 W	63 W	64 W	65 W	66 W	67 W	68 W	69 W
85 W	86 W	87 W	88 W	89 W	90 W	91 W	92 W	93 W	94 W	95 W	96 W	97 W
113 W	114 W	115 W	116 W	117 W	118 W	119 W	120 W	121 W	122 W	123 W	124 W	125 W
141 W	142 W	143 W	144 W	145 W	146 W	147 W	148 W	149 W	150 W	151 W	152 W	153 W

Wood Tie Plugging Compound – Extended Tie Life

- Additional Tie Life for Ties with Loose Spikes
- Plugging Compound Study concluded that plugging ties effectively extends the ties ability to retain spikes.
- Southern Region wood tie project will use plugging compound in 2016.
- Engineering is working on a portable plugging compound solution for surfacing gangs and with maintenance gangs.
- Approximately $2.00 per Tie

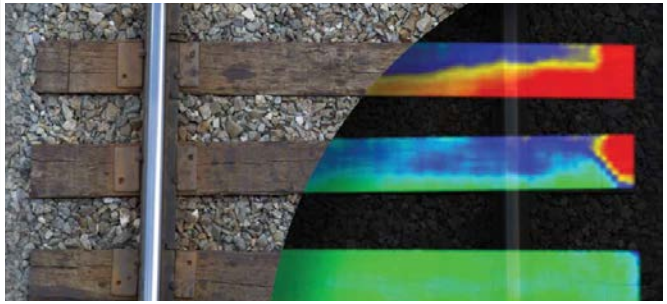
Wood Borate Treated Ties

- **Borate Tie Summary**
  - Extends life of wood ties in high decay locations
  - Extends Tie Cycles in High Decay Zones – Southern Region
  - Eliminates Decay/Stack Burn Air Seasoning
  - Improves performance of creosote ties
  - Prevents Heartwood decay and corrosion around spikes
  - Reduces use of creosote treatment
  - Started in 2014/2015
  - Plan to install 800,000 ties in 2016

2016 Machine Vision Operating Plan

Georgetown Aurora Xi Track Inspection System

- **Wood tie rating evaluation**
  - Laser linescan & x-ray backscatter for 3-D assessment of tie
  - Requires RFID & geolocation coordination to feed UP tie assessment systems
- **2016 Test Plan**
  - Georgetown in testing with RFID receivers
  - UP process to install RFID on track
  - Validation testing on the Southern Region
- **2017 Production target**
  - 2017 tie assessment conducted with Aurora Xi



*** Collateral assessments include joint bar bolt counts, rail anchor evaluation, spike pattern compliance, OTM inventory**

Composite Tie Benefits

*Pine Bluff MP 384, Stamps, AR – 2001 Installation at Over 400 mgt

- Composite Ties
  - Reduce tie interventions
  - Pinebluff Sub install in 2001 has had no wood tie intervention for two cycles
  - Makes hardwood available for other projects
  - Disposal cost do not exists (refund credits)
  - Have had over 150k failures because of manufacture quality.

Composite Ties

Current In-Track Testing Locations

- Test on multiple subdivisions
  - S. Morrill NO 2
  - Chester SIMN
- Three Vendors being tested
  - Axion
  - Carbonloc
  - Integrico
- Long term solution to volatility of wood tie market
- Eliminate Tie Interventions

Concrete Tie Strategy

- Tiered Standards
  - Recessed Rail Seat Tie Testing
  - Bridge Approach
- Tie Pads
- Rail Seat Repair
- Specialty Tie Sourcing
- 14% of Mainline Ties are Concrete
- Concrete Tie Demand in 2016 will be about 300k to 350k

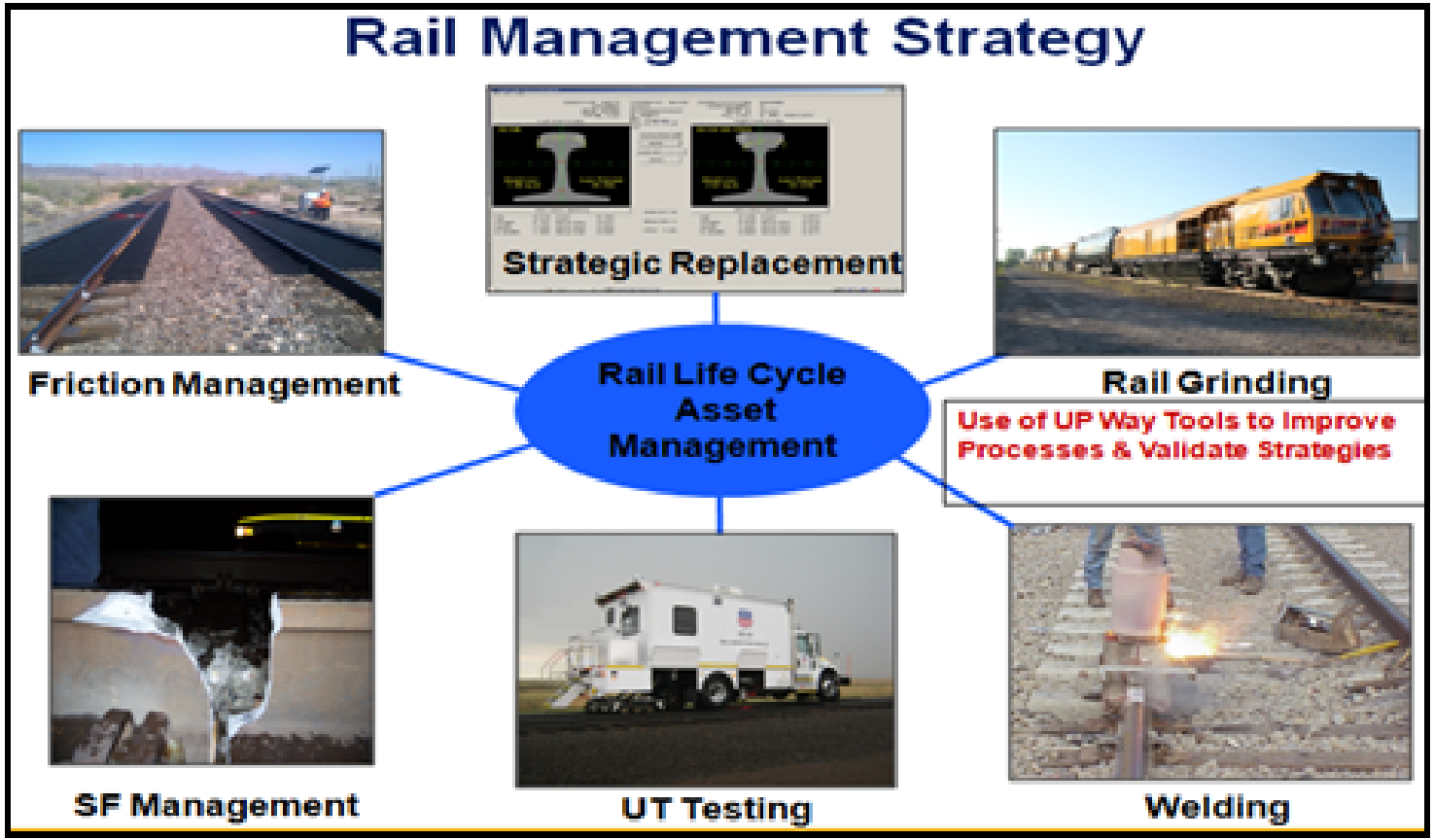
Recessed Rail Seat Tie Testing

- Increased gage life (less insulator replacements)
- Tie Spacing Tests – Increased Spacing

Vossloh W40

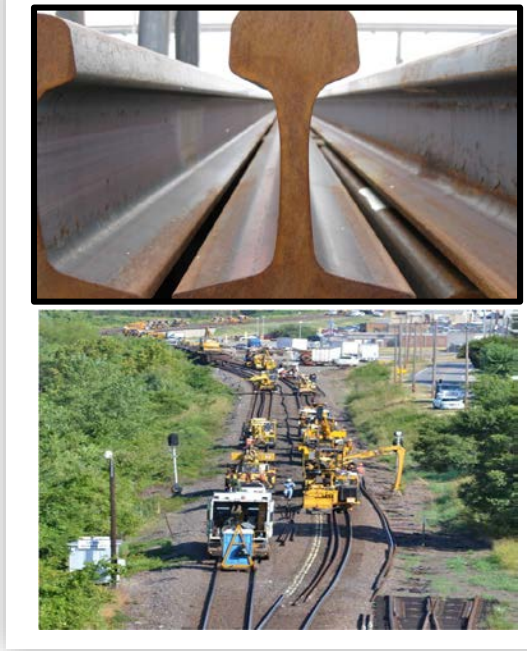
Pandrol FERR

Rail Strategies and Technology



UPRR Rail Facts

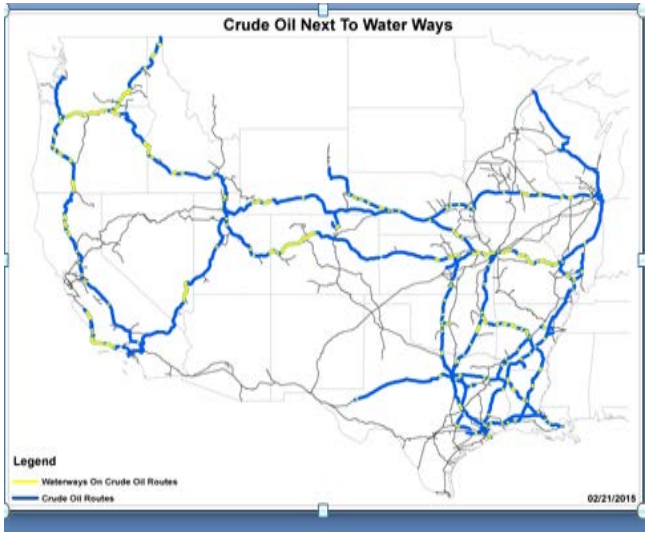
- CWR – Mainline:
  - 3918 TM 5.5” Base Rail, Ave age 49 years old
  - 8851 TM 133# Rail, Ave age 24 years old
  - 10793 TM 136# Rail, Ave age 20 years old
  - 3796 TM 141# Rail, Ave age 7 years
  - 54,716 ML CWR Rail Miles
- Jointed – Mainline:
  - 1263 TM Jointed Rail
- Grinding: 22,261 miles ground in 2015
- DC testing: 134,422 miles
- Top 3 DC defects:
  - DF = 4927 total – 21.4%
  - SSC = 4370 total – 19%
  - DFW-B = 3692 total – 16.1%



Lamella Structure of Rail

Strategic Rail Replacement- New Rail

- New tangent rail driven by rail defects.
- Different defect thresholds for route class.
  - Critical Route = defects/mi/per year
- Rail Replacement Logic (RRL) uses a 2 year RRL fatigue defect average.



- Weighting factors for new tangent rail:
  - Rail Evaluation Index; RRL fatigue defects; shelled, slivered & corrugated (SSC) index, external factors; accumulated tonnage; & rail life expectancy.

- External Risk Factors (Waterways/Population)

Strategic Rail Replacement – New Curve Rail

Curve Replacement Based on Data:

- Measured with track evaluation cars.
- Measures horizontal head wear & vertical head wear, rail head width, rail height, head width, cant & % head loss.
- Curve candidates lists developed based EC measured curve wear, DC high defect curves & “Can’t Test” UT curves.
- Candidate curves inspected & measured by hand by Centralized Engr. curve rater’s & local maintenance inspection forces.
- Rail wear thresholds drive rail repl.
- Curves are prioritized based on inspections, Service Unit & Region input.
- 50% reduction in annual curve rail demand over 7 years.

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Track Welding Strategies & Technology

Track Welding Strategy and Technology

Reduce Risk & Improve Quality

- Evaluating new & improved technology
  - Electronic Straightedge
  - Head Alloy Welds
  - Spark less Rail Cutting
- Improving weld quality processes & Weld longevity
  - Induction Post Heat
  - Thermite Post Heat
- Reducing weld inventory and Cost
  - Head Repair Welds
  - Long Rail
- BNSF invest significantly more than UP in weld QC

Head Repair Weld Strategy

Targeted Detector Car Defects

- 25,956 overall track defects – 5,763 DF Defects – 5,285 DF Defects 60% or less in size

Thermite Head Repair Welds

- On Subdivisions <75MGT
- Limit initial installations to wood tie track (UP)
- Driven by DF defect density
  - Limited to 2-inch length gap
  - 155 welds in track with ~ 100 MGT

Holland “Wedge” Head Repair Weld

- On Subdivisions ≥75MGT
- Detector Car operations on a more frequent cycle allows better monitoring
- Driven by defect type/density
  - SSC/SSC-W defects less than 5 inches in length
  - 51 welds in track with ~ 650 MGT

Benefits

- No replacement rail needed reducing costs associated with materials and labor
- Reduces weld inventory
- Doesn’t have a negative RNT impact

Head Hardened Thermite Weld

Head Hardened Thermite Weld

- Rail head more closely matches the hardness of the rail.
- Softer web and base allows flexing under traffic.
- 6 welds installed on South Morrill Sub. #2 track.
  - Study is in conjunction with TTCI to address surface batter
  - 2 initial welds installed with ~ 188 MGT and no issues

Additional Heat Affected Zone (HAZ) overlay process

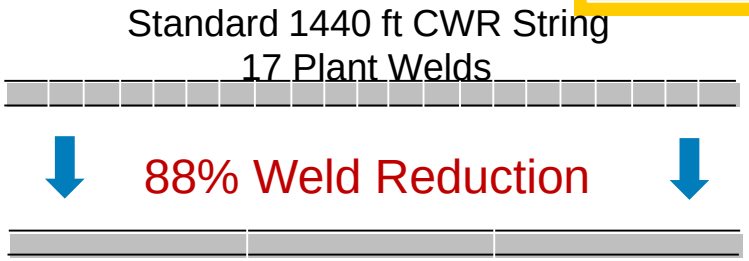
- Reduce surface batter on each side of weld
- Moves and narrows the “soft” HAZ

Perceived Benefit

- Less surface flow and degradation resulting in extended weld longevity

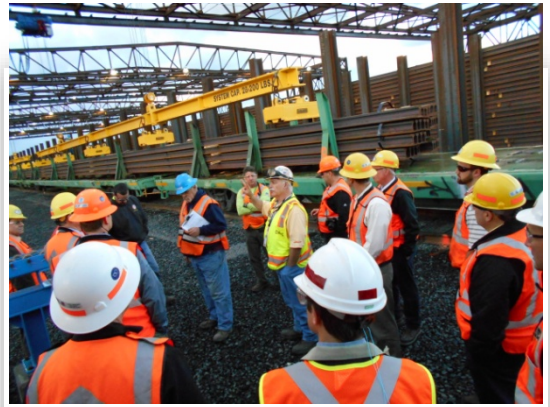
Long Rail Initiative

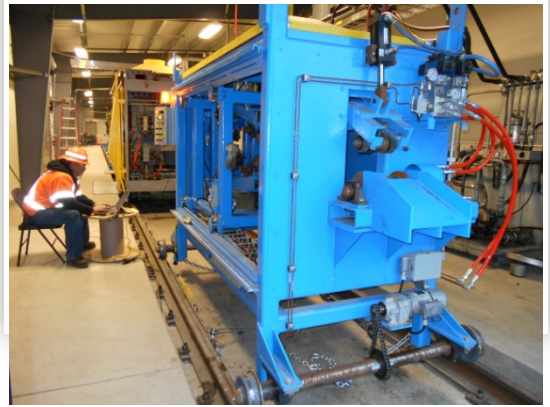
- Rail life is about 4 BGT
- Weld life is about 1.5 to 2 BGT
- Increase rail length from 80 ft. to 480 ft.
  - Eliminates 55 Plant Welds per mile of rail
- Benefits
  - Reduced Risk of Weld Defects
  - Improved Rail Life
  - Reduced Maintenance
  - Improved Service



Long Rail – Welding Plant

- UP Owned\Holland Operated Weld Plant
  - The crane consists of 8 overhead trolley units, 4 spreader beams and 20 magnetic heads.
  - Began welding in March 2015
  - First of its kind.
  - Holds 46,000 tons of rail in storage – Nearly 200 track miles.
  - Designed to make four welds an hour.
  - Can weld two trains a week or 10 miles





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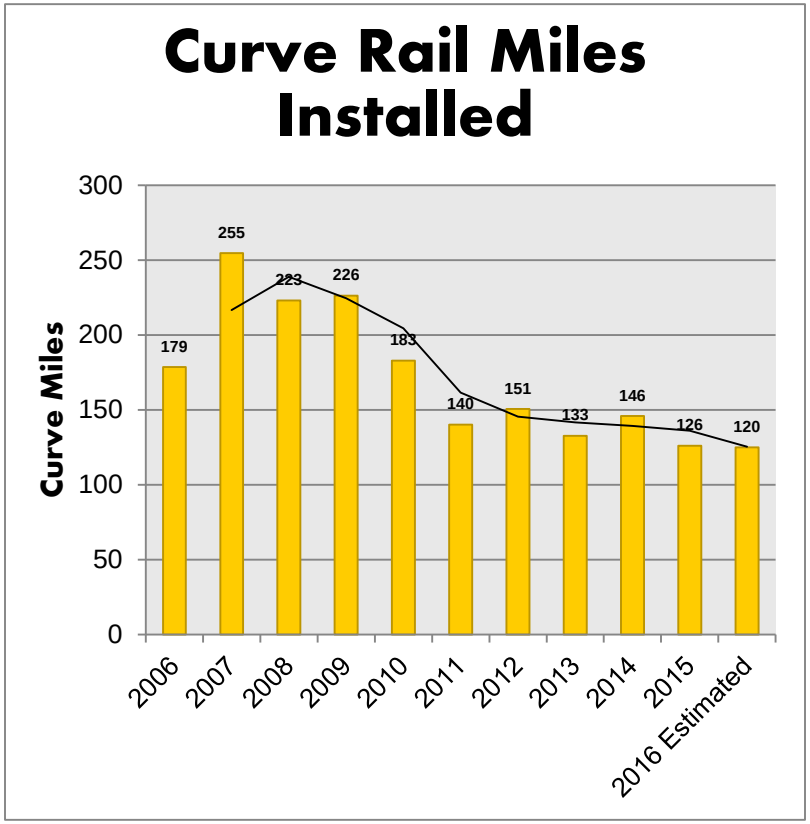
UPRR Friction Management Program

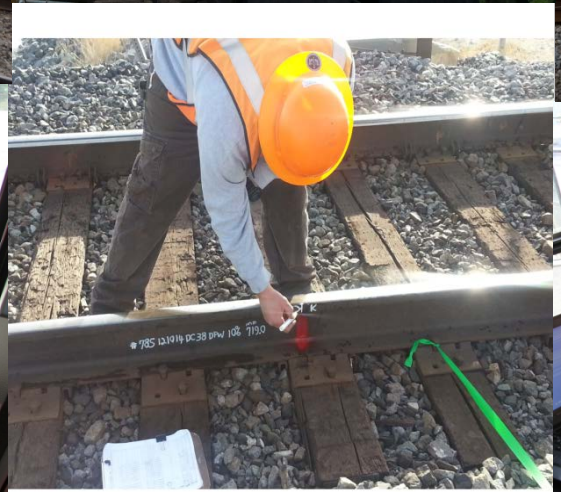
Rail Life Management – Friction Mgmt

Reduces Yearly Curve Rail Demand by Over 45 miles Year

- Strategy
  - Centralized Management
  - Extend the life of rail and components
  - Reduce grinding pass miles
  - Reduce curve rail consumption
- Overall Program
  - Optimal lubrication spacing and coverage
  - Reduce track component degradation (TOR)
  - Reduced Rail consumption (GF)



RAIL TESTING STRATEGIES & TECHNOLOGY

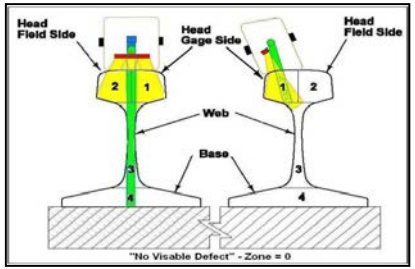


Vendors and Technology

Nordco - 12 DSP - UP Owned

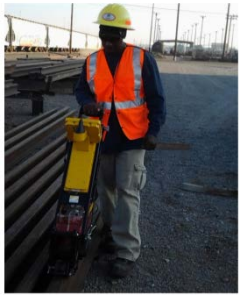
- Pattern Recognition
- Gage Wheel Technology
- Line Scan Cameras
- 4 w/ KLD Laser Rail Profile System

Representation of Nordco's Gage Wheel Technology



Sperry - 8 950/ 4 700 – UP Owned

- Pattern Recognition
- Gage Technology – X-Fire®
- Line Scan Cameras
- 10 B Scan Walking Sticks

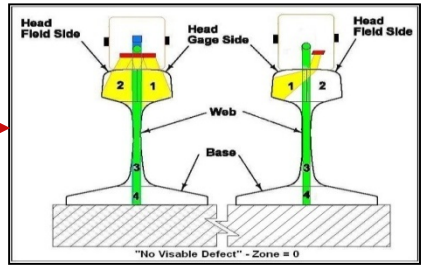


Sperry
(2 Contract as needed)

- Crossfire Wheel Technology –
- Induction Technology

Available

Representation of Sperry Gage Wheel Technology



Small Platform Testing

- Sperry Sprinter Van & Nordco Flex
- 3 Sperry units on property 1/15.
- 1 Additional in December 15.
- 1 Nordco Flex – 10/15
- Miles Per Hour Test Speed up to avg 7.8
- Solid Defect Detection
- New Carriage Designs
- Vision Systems
- Mainline, Yard, Industry Testing
- 30% Lower Operating Cost

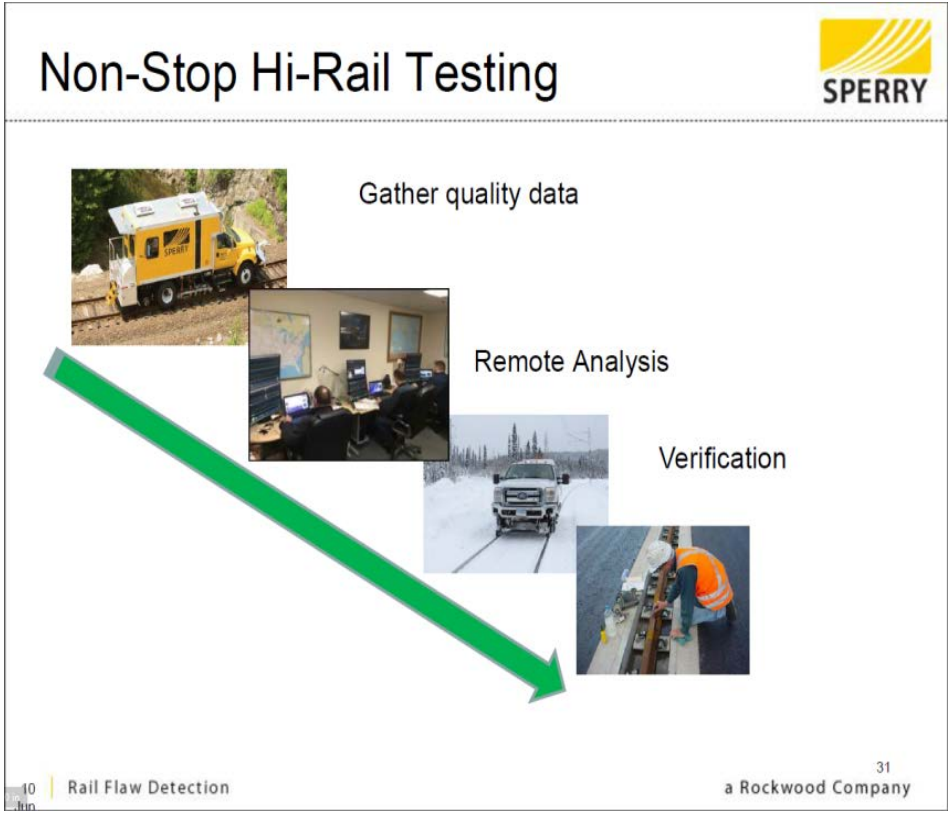
Yard & Industry Testing Strategy

- Herzog unit in Kansas City, St Louis and Chicago.
- Sperry Unit Started in LA – 10/15
- Track Access from Anywhere.
- Fully recordable testing platform.
- Perfect platform for Yard and Industry tracks, CNRT, Critical leads, etc.
- Crew equipped with a Walking Stick to better utilize production time – plug rails, Xovers, Ladder tracks, etc.
- 1 Unit on Each Region in 16
- Sperry will sell units in 17
- Contract Cost is 40% Less

High Speed / Non Stop Strategy

- Required a formal Waiver from the FRA.
- Waiver provides 72 hour delay between test and verification of suspect indications.
- Detector car tests non stop at maximum allowable speed and collects data (20 mph).
- Test data is uploaded every 10 miles.
- Post test results are transmitted back to field verification team within 6 hours of upload.
- Verification team travels via right of way or rail to identified locations to hand verify.
- As frequency of test progresses, anomalies, track structure, etc. is overridden – reduces the number of false positives – allows the D Car to increase test speeds, reduces / eliminates false hand verification.
- Results in faster cycles, smaller / less defects / reduction in slow orders, variability, etc.

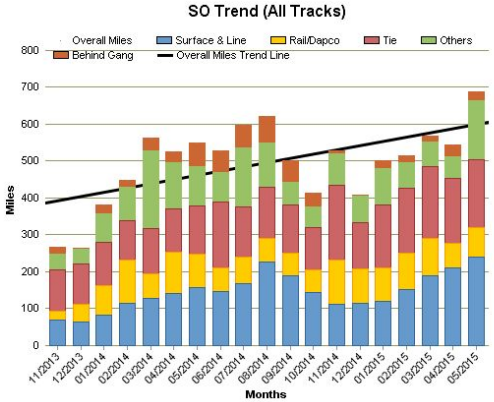
Current Marysville Test started on



Geotech Overview

Geotech assessment leverages stakeholders & technology

- Coordinate with Network Planning to accurately fund and execute projects
  - Chronic Slow Order report
  - Future growth
- Understand risk to the network fluidity generated by landslides, rock slides, wash outs
  - Richmond Slide
  - Minnow Slide
  - Great Salt Lake Causeway
  - Neepas Slide
  - Rockfall mitigation
- Focus on building front line manager understanding of best practices
  - Culvert maintenance
  - Trench drains
  - Shear keys



Geotech Overview

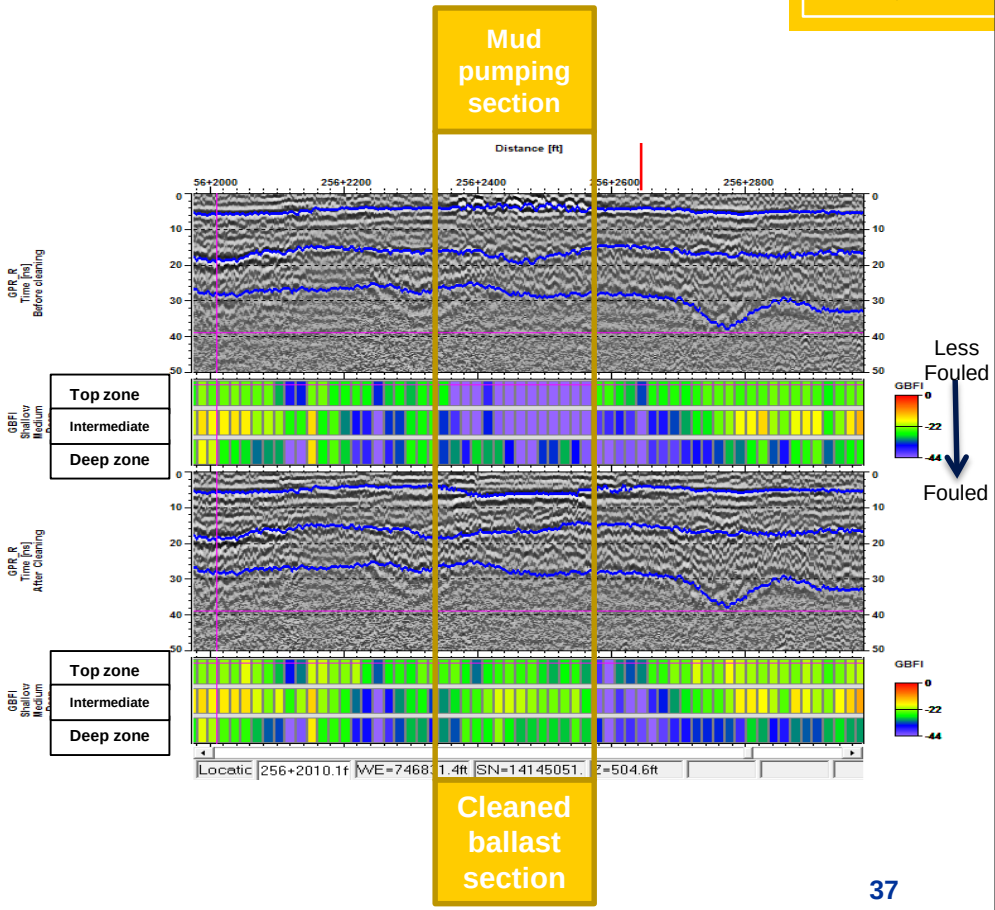
GPR – Ground Penetrating Radar

- Assessment protocol being developed to drive decisions for the BUC undercutting program, approximately $23M in 2016
- The following metrics will combine to drive the undercutting decision process:
  - Fouling Index (from GPR)
    - Remaining Ballast Life
    - Years since last ballast maintenance
  - Route Classification
    - TIH, Passenger
  - Yearly Tonnage
  - Surface and Line Slow Orders
  - Surface Quality Index (SQI)
  - Tie Type, Condition, Previous Cycle

GPR – Ground Penetrating Radar

Springfield Sub MP 256.5 Example from 2014

Right shoulder – before and after undercutting



Ballast Renewal & Maintenance Resources

Surfacing

Asset	Units
3X	4
Regional Dyna-CAT	23
SU Tamper	117

3-6 miles/day

Pro-Active (3X/CAT)

0.25-0.5 miles/day

Re-Active (Service Unit)

Shoulder Cleaning

Asset	Units
Shoulder Cutter (contracted)	2

2-5 miles/day

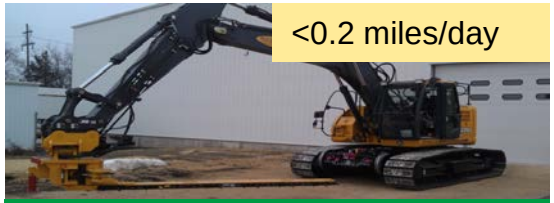
Pro-Active

Undercutting

Asset	Units
On-Track (large)	5
On-Track (small)	6
Off-Track	24

1-2 miles/day

Pro-Active (BUC)



<0.2 miles/day

Re-Active (CBH)

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Track Testing and Assessment

Union Pacific Geometry Assessment

Strategy: Efficiently, effectively assess track geometry condition

Objectives

1. Effective assessment of track geometry to detect risk
2. Multiple platforms to efficiently evaluate variety of track types
3. Meet FRA assessment regulations of concrete tie RSA

Vehicles

- EC 4 & 5 track cars
- Vista hyrails
- Vista Unmanned Geometry Measurement System (UGMS)
- Holland TrackStar trucks

Union Pacific Geometry Assessment

Next steps

Vista Unattended Geometry Measurement System (UGMS)

- Fully autonomous railcar-mounted system (i.e. FRA car on Amtrak)
- Operated in revenue train consist by mid-2016
- Long-term: 3-5 units across network

Vista Hyrail

- 2 additional hyrail units deployed in 2016
- 1 additional CDL hyrail unit for multi-purpose assessment
- Target high risk territories across network

UGMS – Vista Testing Platform

Current Phase to Completion

- Utilizing a UP non revenue car, the project will transform into UP's newest track geometry test platform.
  - Nov 24th: Car will move to Desoto Car Facility for rehab and painting
  - Feb. 2016: Final system will be installed on car. Final validation and testing will begin in consist with EC5.
  - May. 2016: Car will be ready for track geometry testing in consist with revenue train.

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Standards and Technology

Building Engineering effectiveness by improving products and processes